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METHODS AND APPARATUS FOR POTATO PROCESS WATER FILTRATION AND SOLIDS RECOVERY

Inventors:

Jeffery P. Robert
W. Scott Roesener

METHODS AND APPARATUS FOR POTATO PROCESS WATER FILTRATION AND SOLIDS RECOVERY

FIELD OF THE INVENTION

The present invention generally relates to methods for potato process water filtration and solids recovery. More particularly, the present invention relates to apparatus and methods for filtering potato process water and re-using the resulting liquids and solids.

BACKGROUND OF THE INVENTION

In recent years, treating the wastewater from potato processing facilities has become a serious environmental concern, as well as a large expense. These facilities process "raw" harvested potatoes into consumer products such as french fries, criss-cut fries, wedges, hashbrowns, granules, flakes, slices, as well as other various frozen and dehydrated products. Water is used not only in processing the potatoes, but also to move the potatoes through the plant, transport wastes out of the plant, and to clean plant surfaces, process equipment, and floors. In the process, the water becomes contaminated with potato wastes such as leached potato solids, potato pieces, and peel sludge.

There are numerous known processes for processing raw potatoes to make potato products. See, for example, U.S. Patent Nos. 4,251,895, 5,573,795, 5,965,189, 5,549,830, and 6,066,353, the disclosures of which are incorporated herein by reference.

Many of such processes use methods such as peeling, washing, cutting, ricing, blanching, drying, frying, and freezing. The majority of these process steps use water and, therefore, produce water contaminated with potato waste in the form of potato solids. This contaminated water or "process water" can be transported out of the manufacturing plant as a waste product and is therefore known as wastewater. Of all the steps, the peeling, slicing and cutting, precooking, blanching, cooling, and cooking steps typically produce most of the wastewater.

Environmental regulations are becoming more restrictive, requiring more efficient treatment of wastewater. Existing systems for treating wastewater from potato processing have not been successful in removing the potato waste from the wastewater in an efficient and economical manner. In some cases, existing treatment systems do not have the capability to remove enough solids. In other cases, the existing treatments do not efficiently treat the wastewater because they use equipment that becomes obstructed with the potato waste. To clean the systems, the purification systems must be stopped frequently, thus increasing the downtime of the potato processing plant, while reducing the yield and increasing the costs of operation.

As the market for potato products continues to increase, potato processors are expanding their manufacturing plants to increase production and meet the new demand. Such expansions usually increase the capacity of existing lines or add new lines to the existing plant. Existing treatment systems for treating the process water and wastewater,

however, can not often handle the increased load created in the expansion process, or can not handle it efficiently.

SUMMARY OF THE INVENTION

The present invention provides an apparatus and methods for treating process water from potato processing plants. The process water is treated using a dual-step separation process with a first step comprising a filtration process removing suspended solids (i.e., large size particulates) and a second step comprising a filtration process removing dissolved solids (i.e., small size particulates). By capturing the potato solids and recycling them back into the potato process, the yield of the potato process is increased. Further, this process reduces the solids present in the process water, permitting the water to be recycled or used as clean water.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1-6 are views of apparatus and methods for treating process water from potato processing plants. Figures 1-6 presented in conjunction with this description are views of only particular—rather than complete—portions of such apparatus and methods for treating process water from potato processing plants.

DETAILED DESCRIPTION OF THE INVENTION

The following description provides specific details in order to provide a thorough understanding of the present invention. The skilled artisan would understand, however, that the present invention can be practiced without employing these specific details. Indeed, the present invention can be practiced by modifying the illustrated apparatus and method and can be used in conjunction with apparatus and techniques conventionally used in the potato processing industry, such as processes other than just dehydrated flake processes.

There are numerous methods for processing potatoes from raw potatoes to final potato products. The methods are often categorized by the end product: dehydrated, frozen, and refrigerated. The dehydrated products produced include flakes, granules, and slices/dices. Most of these methods, including dehydrated methods, use water and/or steam during their respective processes and, therefore, are called "wet processes."

The apparatus and methods of the present invention can be used to treat process water from any potato process that is a wet process. In one preferred aspect of the invention, the methods and apparatus of the present invention are used to treat process water from any dehydrated flake process, such as the exemplary flake process described below. The present invention is not limited, however, to just dehydrated flake process. Rather, the present invention could be used in any wet process, be it dehydrated or not.

In one exemplary dehydrated flake process, any commercially-available potato can be used to make dehydrated flakes. Preferably, the flakes are prepared from potatoes such

as, but not limited, to Kennebec, Russet Burbank, Idaho Russet, Sebago, Bentgie, Aurora, Saturna, and Mentor. Raw or pre-conditioned potato pieces, slices, nubbins, slivers, or mixtures thereof can be used in the present invention.

The raw potatoes are peeled by any suitable method which removes the peels without damaging the remainder of the potato. One such suitable method peels the potatoes by steam and then the resulting product is inspected to remove defective potatoes. The peeling can also be accomplished by abrasion. The peeled potatoes are then sliced into pieces or "slabs" with a thickness of from about 0.10 to about 1.00 inches, preferably from about 0.3 to about 0.7 inches, and more preferably from about 0.35 to about 0.65 inches. The condensate from the peeling operation is a process water stream.

Next, the raw potato pieces/slabs are optionally washed by any suitable process known in the art, such as those which remove the remainder of the peels. See, for example, U.S. Patent No. 4,251,895, the disclosure of which is incorporated herein by reference. The condensate from the optional washing operation is also a process water stream.

The potatoes can then be precooked by any suitable process. In general, the precook operation is used to gelatinize and gently swell the starches within the potato. The precooker generates an overflow containing suspended and dissolved solids. Thus, any precooking operation which accomplishes this function is suitable and can be employed in the present invention. See, for example, U.S. Patent No. 5,965,189, the

disclosure of which is incorporated herein by reference. The overflow and condensate from the precook operation are process water streams.

If precooked, the potatoes are cooled by any suitable method which lowers the temperature from about 160°F to about 75°F. See, for example, U.S. Patent No. 6,066,353, the disclosure of which is incorporated herein by reference. Typically, the cooling stage uses water to reduce the temperature of the potatoes prior to the cooking operation where the cooking is completed. The overflow from the cooling operation is a process water stream.

Next, the raw potato pieces/slabs are cooked by any suitable method known in the art. In one suitable method, the pieces/slabs are cooked for any time, pressure, and temperature sufficient to evenly and fully cook the pieces/slabs. The ranges of time, pressure, and temperature are known in the art and can be determined through routine optimization procedures. See, for example, U.S. Patent No. 6,066,353, the disclosure of which is incorporated herein by reference. The potato pieces/slabs can also be cooked using a pressurized vessel or superheated steam, where the temperatures and pressures can vary depending on the equipment used and can be determined through routine optimization. The condensate from the cooking operation is a process water stream.

After the cooking operation, the potato pieces/slabs are riced by any suitable ricing process known in the art. During the ricing stage, the potato pieces are forced through a slotted or perforated plate without breaking the cell structure. Optionally, an emulsifier can be added to the wet mash or cooked potatoes as a processing aid before,

during, or after the ricing stage. Additional ingredients such as stabilizers and preservatives, can also be added to the wet mash to improve the storage stability of the dehydrated potato flakes. See, for example, U.S. Patent No. 6,066,353, the disclosure of which is incorporated herein by reference.

After the ricing stage, the potato mash is then subjected to any suitable drying and flaking operation. Such suitable processes include those which dry the potato mash into the desired flakes in either separate stages or in the same stage. Any suitable dryer can be used during this stage, including fluidized bed dryers, scraped wall heat exchangers, drum dryers, and the like. Preferably, a drum dryer is employed in this stage and is well known in the art. See, for example, U.S. Patent No. 6,066,353, the disclosure of which is incorporated herein by reference.

After the drying and flaking operation, the resulting dried sheet is then comminuted. Any method of comminution that minimizes the starch damage, such as grinding, cutting, or pulverizing can be employed in the present invention. See, for example, U.S. Patent No. 6,066,353, the disclosure of which is incorporated herein by reference. After the comminution stage, the potato flakes are packaged and shipped.

The process water from these various stages and processes, like in any stage or operation of a wet process not described above (i.e., blanching), contains varying degrees of potato solids. When discarded, the process water is often called wastewater. The process water from these various stages contains from 0.1 to about 5 wt% potato solids. For example, in the flake process described above, the process water from the peeling,

scrubbing, precooking, blanching, and cooking stages generally contains about 3 wt% potato solids and the process water from the cooling stage contains about 0.1 wt% potato solids.

In the present invention, the process water from the various stages of any potato processing are collected together in a collection means. The collection means of the present invention can be any reservoir which is capable of collecting the various process water streams, temporarily storing them, and then feeding them into the next step of the process as described below. Examples of such reservoirs include tanks and low point drain collection sumps.

Optionally, large potato pieces and peel are then removed from the process water and used as scrap or cattle feed. Such large potato pieces and peel are removed as they could interfere with the purification process downstream or they could lead to unacceptable flake quality if the captured potato solids are returned to a flake process. Thus, the large pieces are preferably removed, as described below, if the concentrate stream from the treatment process is recycled. In one aspect of the invention, potato pieces and peel and other foreign matter larger than 20 mesh are removed from the process water given the tolerance of the downstream treatment process. Should the tolerance of downstream treatment process change, however, such large particulates might be allowed to remain in the process water and be removed downstream. Such larger pieces and peel can be removed using conventional gravitametric or

pressure/vacuum screening equipment, such as those supplied by ROTEX, SWECO, AMIAD, AZO, or US Filter.

After this optional removal step, the process water is treated by any suitable process to obtain a more concentrated potato solids in a concentrate stream and substantially clean water in a permeate stream. Suitable treatment processes are those which treat the process water, yet are able to operate efficiently, such as a substantially continuous process. A substantially continuous process is one in which greater than about 80%, preferably greater than about 90%, of the steady-state production rate of the permeate (permeate flux) can be maintained for at least about 24 hours (preferably for more than about 7 days) before and between cleanings. Figure 5 illustrates the ability of the treatment process of the present invention to operate substantially continuous. Figure 6 illustrates one of the 24-hour periods depicted in Figure 5.

In one aspect of the invention, the treatment process comprises a multi-step separation process. The successive steps of the treatment process remove successively smaller potato solids. For example, the first step of the treatment process removes suspended solids and the next step removes dissolved solids. If desired, additional (or intermediate) stages could be added to remove even smaller (or intermediate-sized) potato solids.

In one aspect of the invention, the first step of the treatment process comprises a filtration process. This filtration process removes suspended potato solids with a size larger than about 0.1 microns. The filtration process can be performed with any suitable

equipment known in the art—such as microfilters or ultrafilters—which efficiently filters out the desired particles from the process water. This filtration process can comprise more than one stage. Indeed, the filtration process can include multiple filtration stages to remove the desired "large" particle sizes. The number of filtration stages depends on the desired concentration and permeate production rate, as well as economic considerations. Preferably, the filtration comprises a two-stage process in series, e.g., a first filtration stage followed by a second filtration stage. The filtration equipment in both stages can be the same or different.

After the filtration process removes such suspended particles, the treatment process continues with the second step by removing dissolved potato solids, also called particles or particulates having a smaller size, e.g., a size larger than about 0.0003 microns. Since particles above about 0.1 microns have been removed in the first step of the treatment process, the particles removed in this second step preferably range from about 0.1 to about 0.0003 microns. This second step of the treatment process can be performed by any suitable process and with any suitable equipment known in the art which filters out the desired particles from the process water. Preferably, a reverse osmosis process (and accompanying equipment) is used in the second step of the purification process.

This second step of the treatment process can comprise more than one stage. Indeed, the second step can include multiple stages to provide the desired concentration. The number of stages depends on the desired purity and yield, as well as economic

considerations. Preferably, the second step comprises a two-stage process in series, e.g., a first reverse osmosis stage followed by a second osmosis stage. The equipment in both reverse osmosis stages can be the same or different.

As illustrated in Figure 1, there are two streams exiting the treatment process of the present invention: the concentrate and the permeate. The concentrate contains a higher concentration of potato solids in an aqueous solution whereas the permeate contains a lower concentration of such solids. The solids concentration in the concentrate generally ranges from about 5 to about 25 wt%, and is preferably about 10 wt%. The solids concentration in the permeate generally ranges from about .001 to about 0.1 wt%, and is preferably about 0.01 wt%.

In another aspect of the invention, the concentrate can be collected from the different steps of the treatment process. In this aspect of the invention, the permeate exiting from the UF system is fed to RO system. One example of this aspect of the invention is illustrated in Figure 2. In this Figure, the first step of the treatment process comprises a UF system and the second step comprises a RO system. In this example, the permeate from the UF system would be fed to the RO system. The permeate then exiting the RO system in Figure 2 would be similar to the permeate exiting the treatment process shown in Figure 1. As illustrated in Figure 2, the concentrate stream from each step (both the UF and RO) would be collected in a collection means. The concentrate stream exiting from the collection means illustrated in Figure 2 would be similar to the concentrate exiting the treatment process shown in Figure 1.

One preferred aspect of the treatment process of the present invention is illustrated in Figure 3. In this aspect of the invention, the treatment process comprises a two-stage UF and two-stage RO system. See, for example, U.S. Patent No. 5,549,830, the disclosure of which is incorporated herein by reference. In the aspect of the invention depicted in Figure 3, the process water was pumped from a feed tank to the first stage of the UF system. If desired, a microfilter could be placed immediately upstream of the UF system.

The process water was then pumped to the first stage of the UF system, thereby producing two streams exiting this first stage: a concentrate that was fed to the second stage of the UF system and a permeate that was directed to the feed tank for stage one of the RO system. The concentrate from stage one of the UF system was fed to the second stage of the UF system, thereby also producing two streams: a concentrate that was directed to the concentrate collection tank and a permeate that was directed to the feed tank for stage one of the RO system.

The contents of the feed tank were pumped to the first stage of the RO system, thereby producing two streams: a concentrate that was directed to stage two of the RO system and a permeate that was directed to the permeate collection tank. The concentrate from stage one of the RO system was fed to the second stage of the RO system, also producing two streams: a concentrate that was fed to the concentrate collection tank and a permeate that was fed to the permeate collection tanks.

Preferably, the UF and RO systems operate as cross-flow filters, rather than dead-end filters. In cross-flow filters, the fluid to be concentrated is continuously recirculated under pressure across the face of the filter membrane. The recirculated fluid sweeps solids off the face of the filter or membrane, helping keep it clean. A small amount of the concentrate is continuously bled out of the system.

The throughput or production rate of the separation or treatment process of the present invention depends on the throughput of the individual steps in the purification process, e.g., the UF system and the RO system. Generally, the throughput (also called the permeate flux) of the UF system and RO system depends on several parameters such as solids concentration, pressure, temperature, cross-flow velocity, materials of construction, compaction of the filter, efficacy of cleaning, and use of enzymes. The throughput of the filtration process, under normal conditions, can generally range from about 20 to about 250 gallons per square foot of filter per day for the UF operation and 2 to 20 GFD for the RO operation.

Typically, the higher the solids concentration in the recirculated fluid, the slower the rate of production of permeate. For the UF system, the total suspended solids (TSS) concentration can range from 0.03 wt% to about 25 wt% Preferably, the solids concentration at the exit of the UF system is about 20 wt%. For the RO system, the solids concentration can range from about 0.2 wt% to about 20 wt%. Preferably, the solids concentration at the exit of the RO system is about 15 wt%.

The throughput of the separation or treatment process of the present invention also depends on the temperature. Generally, the higher the temperature, the higher the permeate production rate. For the UF system, the operating temperature can range from about 150°F to about 250°F. Preferably, the operating temperature of the UF system is about 190°F. For the RO system, the operating temperature can range from about 130°F to about 180°F. Preferably, the operation temperature of the RO is greater than about 140°F. More preferably, the operating temperature is greater than about 160°F. These high temperatures result in increased permeate fluxes of both the UF and RO and enhance the microbiological stability. Additionally, the high operating temperatures inhibit growth of thermophillic anaerobes, greatly contributing to the substantially continuous operation of the treatment process.

The pressure also impacts the throughput. The pressure across the filter membrane, known as the transmembrane pressure (TMP), is the average pressure on the recirculation side of the membrane minus the pressure on the permeate side of the membrane. In ultrafiltration, the permeate production rate increases with the increase in TMP up to a "critical pressure," e.g., that point at which the build-up of materials at the surface of the membrane causes a resistance to permeate flow that just offsets the gain due to the pressure increase. Above the critical pressure, little to no increase in permeate rate is obtained.

For the UF system, the pressure can range from about 20 to about 50 psi. Preferably, the operation occurs at about the critical pressure +5/-0 psi, e.g., under normal

conditions, at about 30 psi. Operation at these conditions significantly increases permeate flux with no effect on continuous operation. With the RO system, however, the permeate production rate generally increases with the increase in TMP with no observed "critical pressure." The pressure in the RO system can typically range from about 200 to about 450 psi.

The throughput of the treatment system also depends on the materials used to construct the filter or RO membrane. Certain materials tend to compact more than others, and certain materials are more difficult to clean. As the filter or membrane compacts, the permeate flow rate drops. Filters that can't be clean must be replaced. Thus, materials which do not tend to compact under the operating conditions and that can be cleaned are employed in the present invention.

For the UF, inorganic filters can be employed as the filter. Examples of inorganic filters include metal and metal alloys like stainless steel, ceramics, and combinations of metals and ceramics. Preferably, ceramic membranes supported on sintered stainless steel are employed as the UF filter in the present invention. More preferably, the Scepter™ Stainless Steel/Ceramic Ultrafilter (sold by Graver Technologies of Delaware) is used as the UF filter. For the RO membrane, high temperature membranes are employed. Preferably, high-temperature organic membranes are used as the RO membrane. More preferably, the Duratherm Excel ™ Reverse Osmosis Membrane (sold by Osmonics DESAL) is used as the RO membrane.

Cross-flow velocity, the rate at which the fluid is recirculated across the face of the filter membrane, also affects the throughput. Generally speaking, the higher the cross-flow velocity, the higher the permeate production rate. Any suitable cross-flow velocity can be employed in the present invention. With an ultrafiltration system, the cross-flow can range from 3 up to about 18 feet per second (fps), equivalent to a volumetric flow rate of 100 to 600 gpm for an 8-inch diameter, two pass filter. When suspended solids concentration in the UF is less than about 5%, the higher flow rate provides a higher permeate flux. However, when suspended solids concentration is greater than about 5%, the effect of cross-flow is significantly diminished, and it can be economical to use the lower flow rates. For example, with a 4-inch diameter RO system, the cross-flow rate can range from 10 up to about 30 gpm. Preferably, 30 gpm is used as the cross-flow rate in the RO.

Optionally, additives can be added the wastewater before or during the filtration process. Such additives can perform many functions, such increasing the permeate production rate, decreasing obstruction in the filtration equipment, and increasing the attainable concentration. One important type of additive is enzymes. See, for example, U.S. Patent No. 6,066,353, the disclosure of which is incorporated herein by reference. More than one enzyme can be employed in the present invention, if desired.

Enzymes can be added for various purposes such as degrading the starch or degrading the potato cell walls, as well as to increase the throughput. See, for example, U.S. Patent No. 5,573,795, the disclosure of which is incorporated herein by reference.

Any suitable enzyme known in the art can be used, such as proteases and amylases. Preferably, an alpha-amylase—such as BAN enzymes (sold by Novo Nordisk)—is used as the enzyme added in the filtration process in the present invention. Preferably, the enzyme is fully captured in the UF system, and does not pass to the RO system.

The amount of enzyme added depends on the type of enzyme added, the throughput of the filtration process, the temperature, the pH, the amount of solids, the character of the solids, the type of filtration used, and, as described below, the time since the last cleaning of the filter. The amount of enzyme added ranges from about 0.08 ml to about 0.4 ml enzyme per pound potato solid feed. Preferably, about 0.2 ml enzyme per pound of solid feed is used in the present invention. Although they can be added batch-wise, the enzymes are preferably added on a continuous basis.

Addition of enzyme to the UF system can result in throughput about 2 times higher than when no enzyme is present. In addition, when no enzyme is present, the UF system can not be operated above 175°F since above this temperature, the permeate flux is not sustainable. If an enzyme is included in the UF system and is lost at such a high temperature, a sustainable permeate flux can be restored by cooling the UF system to below 140°F, restoring the enzyme, and holding the temperature for two hours.

The preferred UF system and RO system should be periodically cleaned to insure maximum efficiency and maximum throughput. Any suitable cleaning process known in the art to clean the UF and RO equipment and substantially or fully recover the filter can be used in the present invention.

For the UF equipment, a high temperature cleaning with a caustic/hypochlorite mixture completely recovers the filter, e.g., the flux measured while recirculating clean, soft water, was the same as that measured on the filter when it was new. Any caustic material, such as sodium hydroxide, can be used in this cleaning process. Cleaning temperatures above 180°F were typical since at lower temperatures, cleaning was much slower and not as effective in restoring throughput. If necessary, an additional acid cleaning could be periodically performed on the UF equipment. Caustic and hypochlorite are preferably used together in the cleaning process because caustic alone can result in plugging of the filter. Preferably, a 2% caustic solution is employed in the UF cleaning. The hypochlorite concentration should be maintained greater than about 100 ppm, preferably greater than about 500 ppm, and more preferably greater than about 1000 ppm. The pH of the cleaning should be greater than about 12.5, and is preferably greater than about 13.5.

The UF equipment should be cleaned periodically to maintain the permeate flux at or above 80% of steady-state as illustrated in Figure 5. In one aspect of the invention, the UF equipment can be operated for at least one week without a caustic/hypochlorite cleaning and for at least six weeks without an acid cleaning. By fully recovering the UF, it does not decline from its "new filter" flux and, therefore, need not be oversized to account for degradation. By being cleaned less than once per week, the UF system of the present invention operates on a substantially continuous basis.

The RO equipment also needs to be periodically cleaned. In one aspect of the invention, the RO system can be operated for at least 24 hours without requiring a chemical cleaning cycle. Any suitable cleaning process which substantially recovers the efficiency of the RO equipment can be used in the present invention. In one aspect of the invention, a four-step cleaning process with the following washes was used: first, alpha-amylase at 160°F; second, acid at 120°F; third, protease at 120°F; and fourth, caustic at 120°F. The high temperature cleaning is required to remove biological foulants. By being cleaned less than once per day, the treatment process of the present invention operates on a substantially continuous basis.

The permeate stream exiting from the treatment process of the present invention is clean water. Generally, the concentration of the potato solids in this permeate stream is less than about 0.1 wt%. Preferably, the concentration of the potato solids in this permeate stream is less then about .01 wt%. This permeate stream can be used to any purpose consistent with the potato solids concentration. For example, this permeate stream can be used as a recycle stream in the wet processes of the potato processing plant as illustrated by the dashed lines in Figure 4. In another example, if further polished and biologically stabilized, the permeate stream can be used as clean-in-place (CIP) make-up water. If desired, this permeate stream can also be further purified by other means to obtain potable water. Additionally, this permeate stream could be used for agricultural purposes.

The concentrate stream exiting from the treatment process generally contains from about 5 to about 25 wt% solids and preferably contains about 20 wt% solids. This concentrate stream can be used for many purposes. First, the concentrate stream can be used for fermentation or as an animal feed. Second, through any well known evaporation technique, the concentrate stream can be further concentrated to a solids concentration greater than about 90 wt%, and preferably about 93-95 wt%. Such high concentrations are known as a bone-dry solids (BDS), and are used for other value-added potato products.

As illustrated by the dashed lines in Figure 4, the concentrate stream can also be returned or recycled to a process for making dehydrated potato flakes. By returning potato solids, which were previously discarded without the treatment process of the present invention, the yield of the flaking process can be increased by up to about 5%. In this aspect of the invention, the concentrate stream can be added to the discharge of the cooker before the ricing stage, thereby ensuring homogenization. For example, about 0.1 to about 3 gpm concentrate with a concentration between 5 and 25 wt% could be added to the stream entering the ricer in a flake process that produces 5000 pounds of potato mash per hour.

In similar aspect of the invention, the concentrate stream can be fed to the drying and flaking stage, such as a drum dryer. For example, about 0.1 to about 3 gpm concentrate with a concentration between 5 and 25% could be added to a drum dryer in a flake process that produces 1000 pounds of potato product per hour.

The following non-limiting example illustrates the present invention.

Example 1

A two-stage UF system and two-stage RO system as illustrated in Figure 3 was employed to treat process water. A 20 mesh filter was used to prescreen the process water.

A 0.1 micron ceramic UF filter manufactured by Graver Technologies was used in both stages of the UF. Several tests were conducted to determine the operating parameters of the UF system. The important test parameters and results are summarized in Table 1.

Table 1: UF System

Test	Cross Flow (gpm)	Face Velocity (fps)	Trans-Membrane Pressure (psi)	Temperature UF 2 (°F)	VRF UF 2	Total Suspended Solids (%)	Total Solids (%)	Permeate Flux UF2 (gfd)
1	600	18	10 to 50	170	2	No Data	No Data	30 to 85
2	300	9	30	165	2	4.8	6.4	10
3	300	9	35	140	10	5.4	7.2	20 to 10
4	100	3	35	170	30	17.3	18.9	15
5	540	18	32	175	10	5.4	8.1	71
6	530	16	33	180	13	8.4	10.9	39
7	390	12	24	180	18	10.8	14.1	28
8	100	3	42	200	28	16.6	20.4	22
9	600	18	35	170	2	2.2	4.5	110
10	300	9	30	160	No Data	1.5	4.1	79
11	300	9	37	180	No Data	15.4	18.4	27

A two-stage, high-temperature, sanitary RO skid was obtained from Osmonics. The Osmonics skid was operated at high temperature with no biological fouling occurred. Five tests were conducted to determine the operating parameters of the RO system. The

important test parameters and results are summarized in Table 2. The last test was run for 24 hours. The permeate flux at the end of 24 hours was holding steady.

Table 2: RO System [Sorted by Volume Reduction Factor (VRF)]

Test	VRF	Pressure (psi)	Temperature (°F)	Measured Total Dissolved Solids (%)	Average Permeate Flux (gfd)	Calculated Average Total Dissolved Solids (%)
4	4.3	260	160	No Data	2.8	9.89
4	4.2	290	163	8	2.2	9.66
3	4.1	260	161	9.5	2.6	9.43
4	2.5	290	163	No Data	8.7	5.75
4	2.4	260	160	No Data	9.2	5.52
3	2.4	260	161	No Data	8.8	5.52
2	2.6	210	164	5.4	5.8	5.98
1	2.2	210	167	4.7	9.9	5.06
5	2	210	166	4.8	10.3	4.6
2	1.9	210	164	No Data	11.2	4.37
2	1.7	210	163	No Data	12.1	3.91
1	1.5	210	167	No Data	14.6	3.45
5	1.4	210	166	No Data	15.2	3.22
2	1.4	210	163	No Data	16	3.22

A test was performed to determine if concentrate from the two-stage UF and two-stage RO could be returned to a dehydrated flake process. The concentrate from the RO system at a VRF of 2 and UF system at a VRF of 25 were mixed and fed for 8 hours to a flake drum at a rate of about 0.65 gpm. The drum ran without incident, the drum operator noticed no effects, and the product produced, a potato flour, was normal in all respects.

Having described the preferred aspects of the present invention, it is understood that the invention defined by the appended claims is not to be limited by particular details set forth in the above description, as many apparent variations thereof are possible without departing from the spirit or scope thereof.